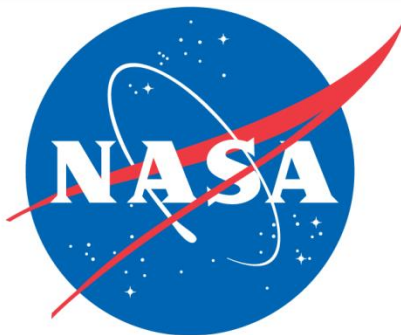# FLIGHT PROJECTS DIRECTORATE

EARLY WARNING LOOK AHEAD METRICS: THE PERCENT MILESTONE BACKLOG METRIC

IEEE AEROSPACE CONFERENCE

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Agenda

- Introduction
- The Early Warning Look Ahead Metrics
- Differences Between Early Warning Look Ahead Metrics and Earned Value Management Metrics
- The Percent Milestone Backlog Metric
- Example
- Conclusions

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Introduction

- All complex development projects experience delays and corresponding backlogs of their project control milestones during their acquisition lifecycles
- NASA Goddard Space Flight Center (GSFC) Flight Projects Directorate (FPD) teamed with The Aerospace Corporation (Aerospace) to develop a collection of Early Warning Look Ahead metrics that would provide GSFC leadership with some independent indication of the programmatic health of GSFC flight projects
- As part of the collection of Early Warning Look Ahead metrics, the Percent Milestone Backlog metric is particularly revealing, and has utility as a stand-alone execution performance monitoring tool
- This paper describes the purpose, development methodology, and utility of the Percent Milestone Backlog metric
- The other four Early Warning Look Ahead metrics are also briefly discussed
- Finally, an example of the use of the Percent Milestone Backlog metric in providing actionable insight is described, along with examples of its potential use in other commodities

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Early Warning Look Ahead Metrics Overview

- **Look Ahead Metrics** provide a concise, graphical representation of the past, current, and potential future state of the programmatic health of a project
  - Has similarities to EVM, but is not the same thing – this looks at a project from a different viewpoint, and has a different underlying basis
  - Examines milestone completion rate, milestone backlog, spending rate, and ability to finish all milestones on time
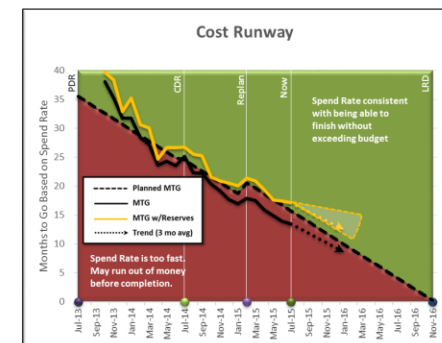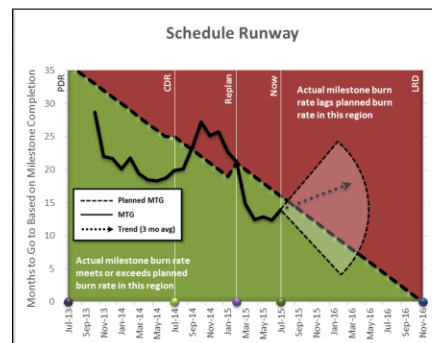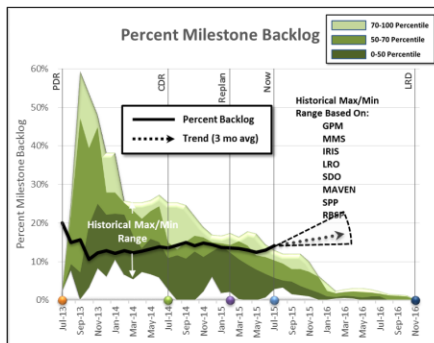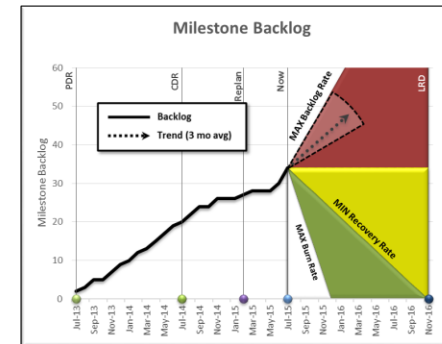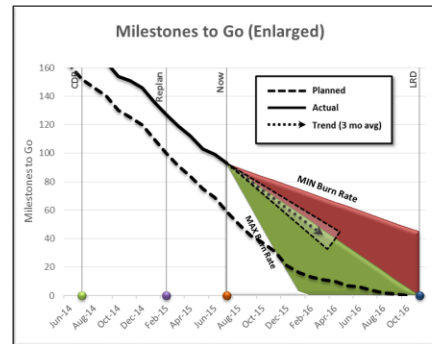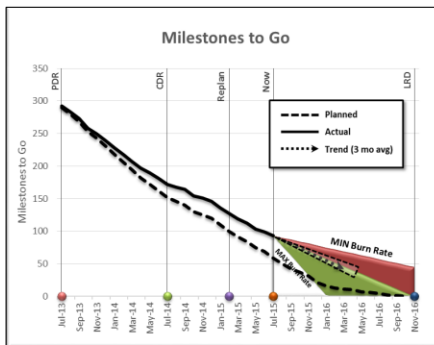
Early Warning Look Ahead Metrics Definitions

- **Milestones to Go Metric** depicts the number of actual vs. planned milestones remaining until project completion
  - Is the project completing milestones in accordance with the plan?
  - Is the project on a path to complete all milestones in time to finish?
- **Milestone Backlog Metric** depicts the actual milestone backlog each month
  - Is the milestone backlog growing or shrinking?
  - What is the backlog trajectory? Is the project on a path to recover?
- **Percent Milestone Backlog Metric** enables direct backlog comparisons to other projects that have been successful
  - Is the milestone backlog something to be concerned about at this point in the project?
  - Have other projects had this level of milestone backlog and recovered?
- **Schedule Runway Metric** depicts the number of months needed to complete all remaining milestones, given the recent milestone completion rate, and compares to actual amount of time remaining
  - Does the project have time to complete all remaining milestones?
  - Does the project need to increase its milestone completion rate?
- **Cost Runway Metric** depicts the number of months of spending capacity remaining given recent spending rates, relative to the cost to go, and compares to actual amount of time remaining
  - Is the project spending money at an appropriate rate to finish at or under budget?
  - Does the project need to modulate its spending rate?

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Milestone Performance Metrics

- **Milestone Performance Metrics** measure the degree to which project control milestones are backing up and being shifted to the right over time
  - A project that is falling behind in completion of its milestones will "push" those milestones out to the right, creating a "bow wave" of milestones yet to be completed
  - Impacts ability to finish project on time

- **Milestones-to-Go** depict the number of actual versus planned milestones remaining until project completion
- **Milestone Backlog** depicts the actual milestone backup each month
- **Schedule Runway Metric** depicts the number of months needed to complete all milestones on time, given the recent milestone completion rate
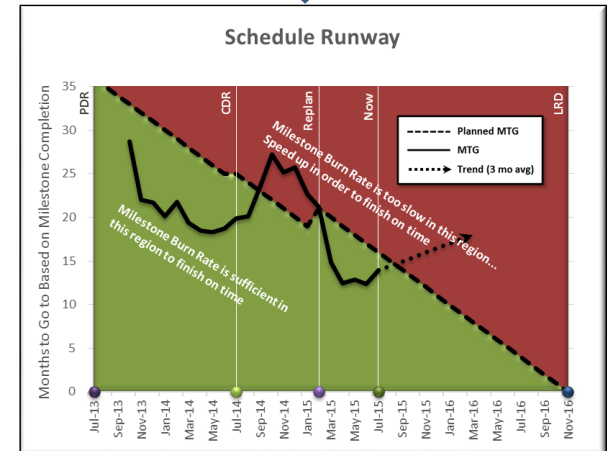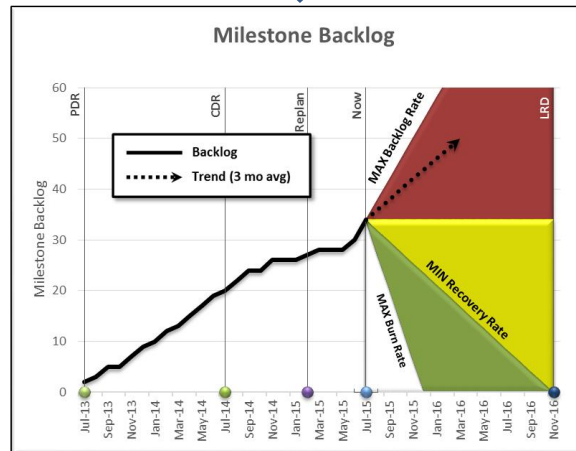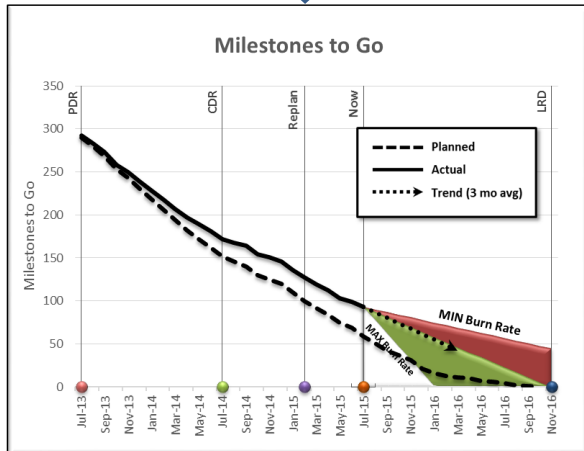
Cost Performance Metric

- Cost Runway Metric indicates whether or not a project has enough unexpended cost remaining at its current spend rate to make sure it is on a trajectory to finish before running out of money
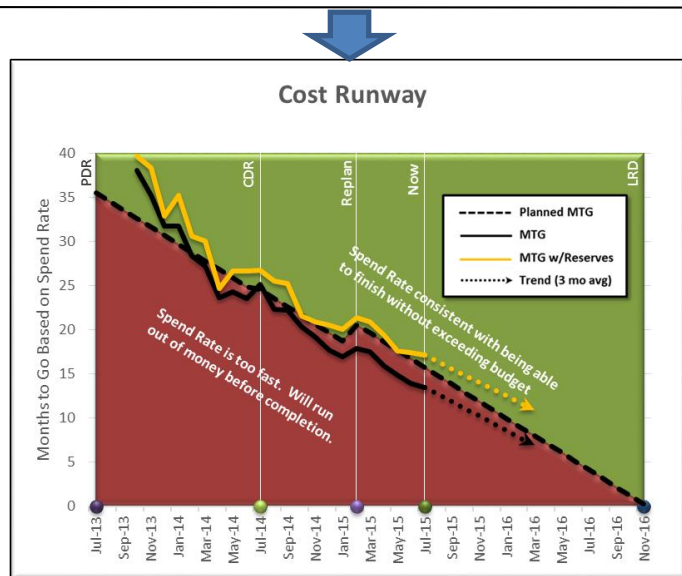
- Cost Runway Metric is the ratio of the Cost-to-Go to the 3-month average spend rate, and represents the number of months of spending capacity remaining until available funds are expended under recent spend rates

  – If Milestones to Go Metric is less than the number of months remaining to Launch Readiness Date (LRD), then the project is in danger of running out of money before reaching LRD – the spend rate is too fast

  – Milestones to Go Metric w/Reserves is calculated using Cost-to-Go (plus reserves)

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Example Combined Look Ahead

- Combined Look-Ahead for EXAMPLE is mixed
  - Milestone completion rate has remained steady and is converging to the plan, meanwhile, the backlog is increasing and trending unfavorably, and exceeds historical limits for successful projects, but, nonetheless, sufficient time remains to complete all milestones
  - Spending rate is consistent with finishing on budget and trending favorably
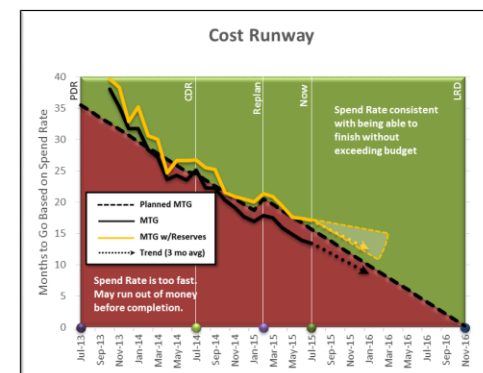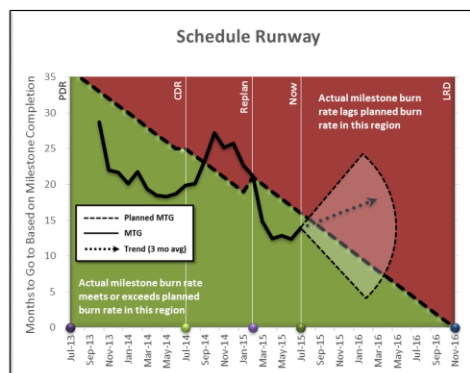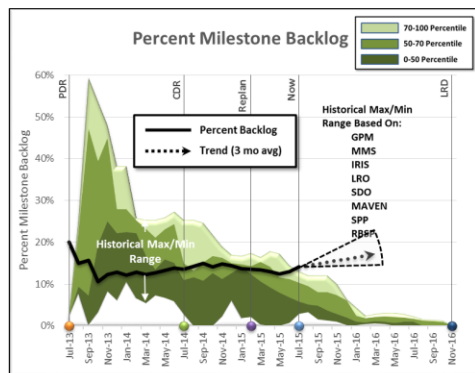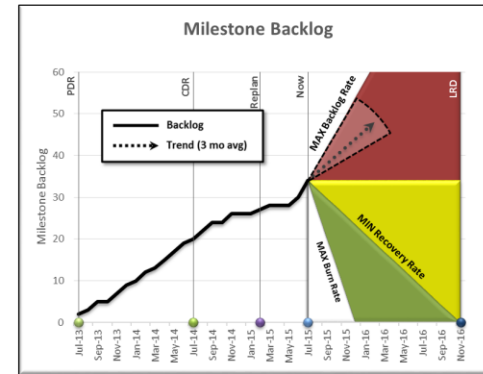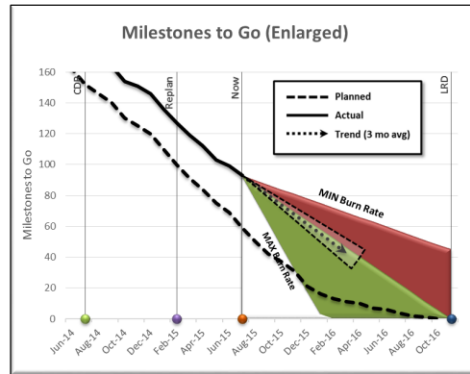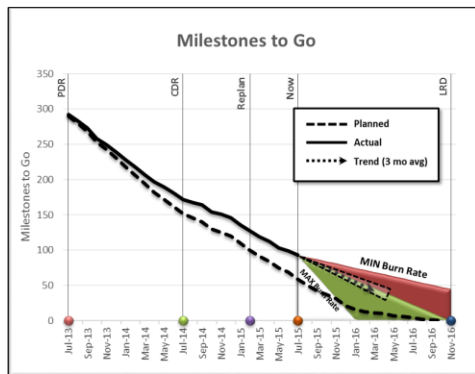
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Wait! Isn't This the Same as EVM?

- No! Early Warning Look Ahead metrics are (mostly) independent of EVM
  - Some obvious similarities to EVM, but uses a different basis
  - Schedule basis is control milestone completion; reports milestones-to-go, milestone backlog, and months-to-go
  - Cost basis is monthly spending vs. development cost-to-go; reports months of spending capacity remaining
- Most NASA flight projects utilize EVM to measure cost and schedule performance, but GSFC sought an additional, independent method of evaluating the programmatic health of its flight projects
  - Early Warning Look Ahead metrics complement EVM metrics
  - A "second opinion," combined with other traditional EVM and performance metrics, to describe overall health of GSFC flight projects
- But, not all projects utilize EVM. The Early Warning Look Ahead metrics can be constructed in lieu of EVM for projects that have chosen not to use EVM to monitor performance
- The two types of metrics together provide a more complete picture of project performance than either type used alone

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Agenda

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The Percent Milestone Backlog Metric

- The Percent Milestone Backlog Metric provides actionable insight to GSFC management on the milestone execution performance of its flight projects
  - Is the project in a state of backlog that no other successful project has been in?
  - Is the backlog "normal" for the project at this point in time?
  - Is it time for management intervention?
- A tool to monitor schedule and milestone completion performance
  - Compares to similar, successful, projects
  - Provides indication as to whether the backlog is "normal" or "in extremis"
- Developed for GSFC Flight Projects Directorate, but could be adapted to a broader range of projects; with analogous performance data, could be applied to industry or other government agencies
- This paper will discuss
  - Purpose
  - Development Methodology
  - Utility

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Purpose of the Percent Milestone Backlog Metric

- It is not enough to compare a project's milestone completion performance to its own plan
  - Every project has a different plan and a different number of milestones
  - How do we know if a project's backlog is "going off the rails?"

- Should also be able to compare a project's milestone completion performance to a collection of other successfully delivered projects. Have other projects had a backlog of this size and still delivered?

- The Percent Milestone Backlog metric allows us to compare a project's milestone backlog to historical norms
  - If the Percent Milestone Backlog falls within the "region of normal," then there is no apparent cause for alarm
  - If it has departed the "region of normal," then it may be time for management intervention

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Development Methodology

- Underlying metrics are the Milestone Backlog and the Cumulative Planned Milestones for a given month
  - The Percent Milestone Backlog for a given month is computed as

$$Percent\ Milestone\ Backlog =$$
$$Current\ Milestone\ Backlog/Current\ Cum\ Plan$$

  - This tells us the percent backlog of a given project in a given month
  - But, to develop a basis of comparison to other projects, normalization is required
- The first step was to collect milestone performance data, both planned and actual, for a collection of historical flight projects that were successfully delivered, or close to delivery
- Selected projects included:

ASTRO-H	SWIFT	GPM	LRO	SPP	OSIRIS-REx	ICON
Aquarius	SAM	MMS	SDO	ST-5	GOES-R	
LOLA	SMAP	IRIS	MAVEN	RBSP	GOLD	

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Development Methodology (2)

- The projects' milestone performance data were obtained from their respective project Monthly Status Reports (MSRs)

  - An example of a typical milestone status chart is shown below

Cumulative Milestone Performance Status
Status as of: Aug 2014

From Project Reports
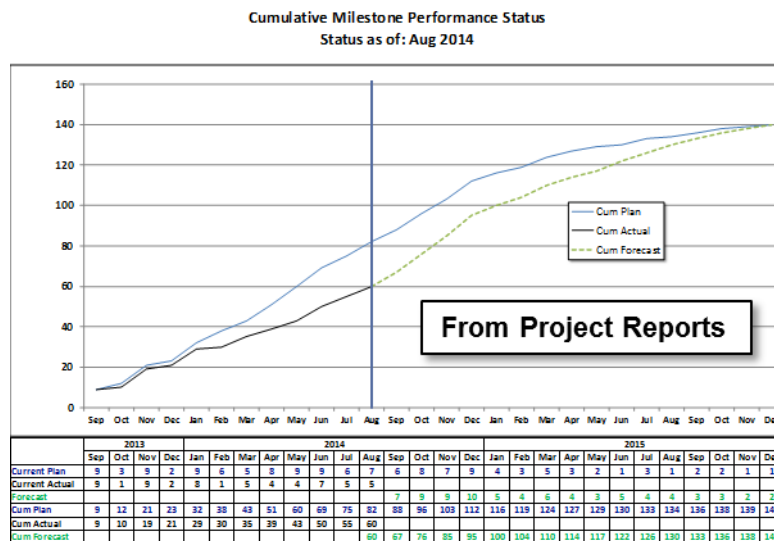
  - From these charts, Percent Milestone Backlog metrics were computed for each month of the project's development lifecycle from Preliminary Design Review (PDR) to LRD or delivery

Development Methodology (3)

- The second step was to normalize each historical project's schedule to a 0% (PDR) to 100% (launch or delivery) percentage schedule using a simple interpolation scheme. This enabled a consistent basis of time for each historical project

- The third step was to calculate the percent milestone backlog of each historical project against the normalized schedule from PDR to launch or delivery
  - For example, suppose in September a flight project had a 38% milestone backlog at 17% of its schedule from PDR to launch or delivery, then in October the same flight project had a 43% milestone backlog at 19% of its schedule
  - We would interpolate the intervening 18% schedule as having a percent milestone backlog of 40.5% by interpolation as follows
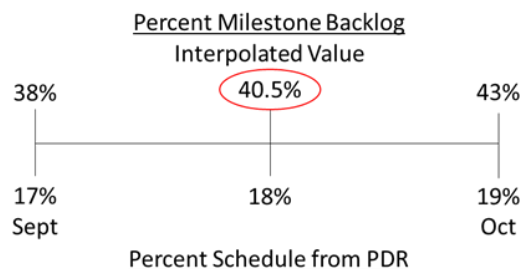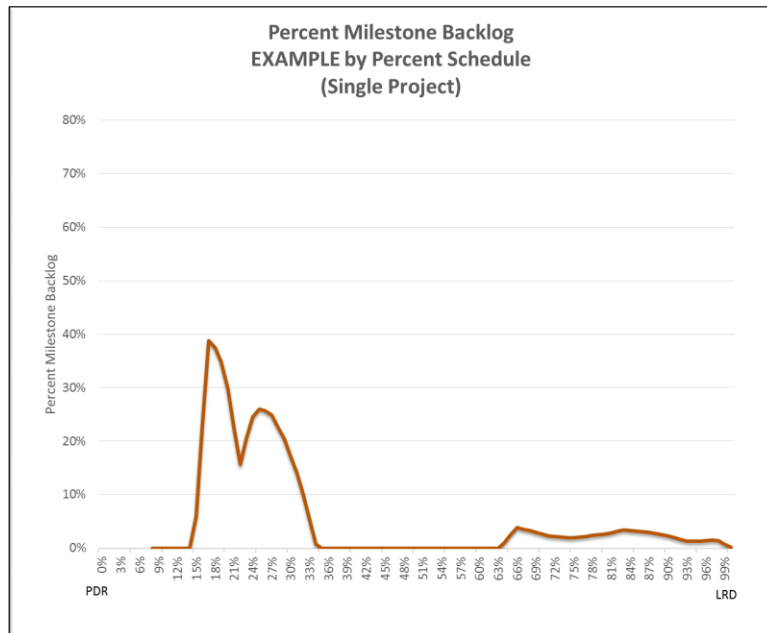

  - This process was repeated for each unit schedule percentage from 0% to 100%

Development Methodology (4)

- The graphs shown below illustrate plotting the percent milestone backlog for one project, and also for the entire collection of projects

Single Project

Percent Milestone Backlog
EXAMPLE by Percent Schedule
(Single Project)

Collection of Projects

Percent Milestone Backlog
EXAMPLE by Percent Schedule
(Individual Projects)

Historical Max/Min
Range Based On:
ASTRO-H	SDO
Aquarius	MAVEN
LOLA	SPP
SWIFT	ST-5
SAM	RBSP
SMAP	OSIRIS-REx
GPM	GOES-R
MMS	GOLD
IRIS	ICON
LRO	

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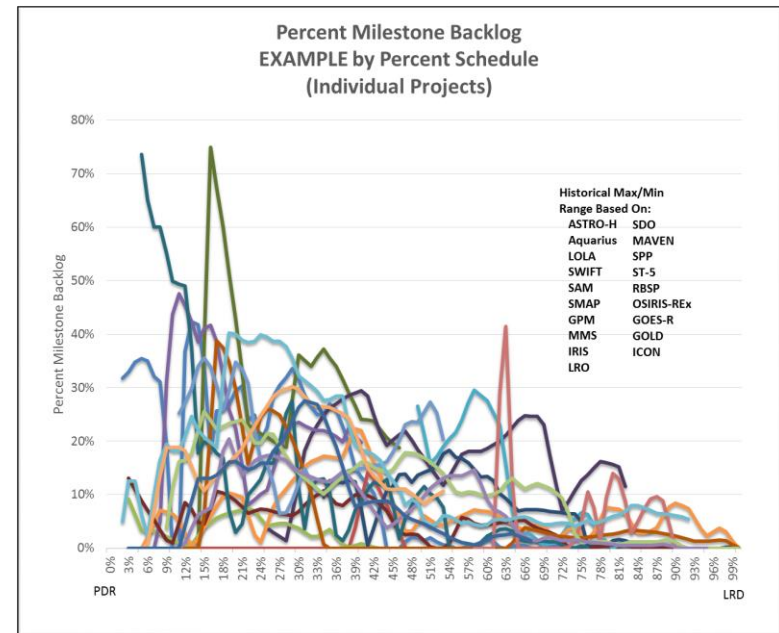
Development Methodology (5)

- The fourth step was to define the region described by all of the historical projects as the "region of normality." Then, for each percentage point along the 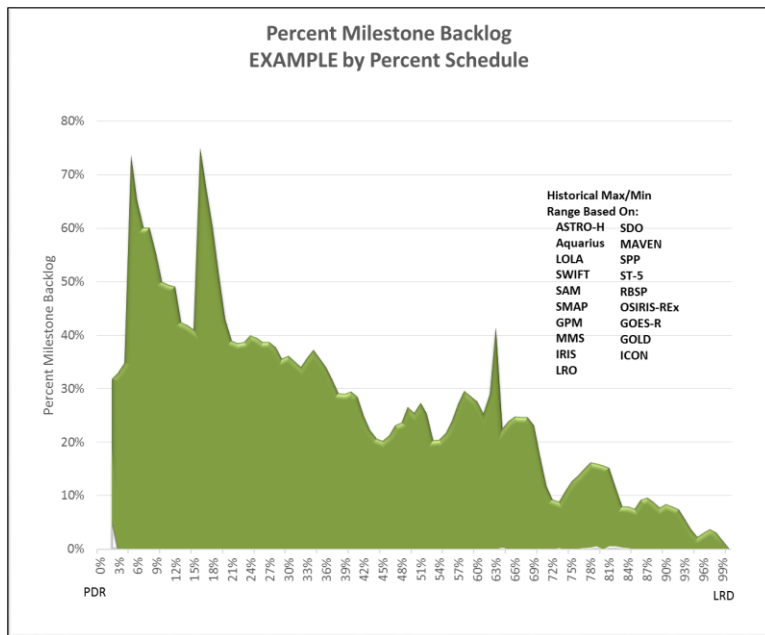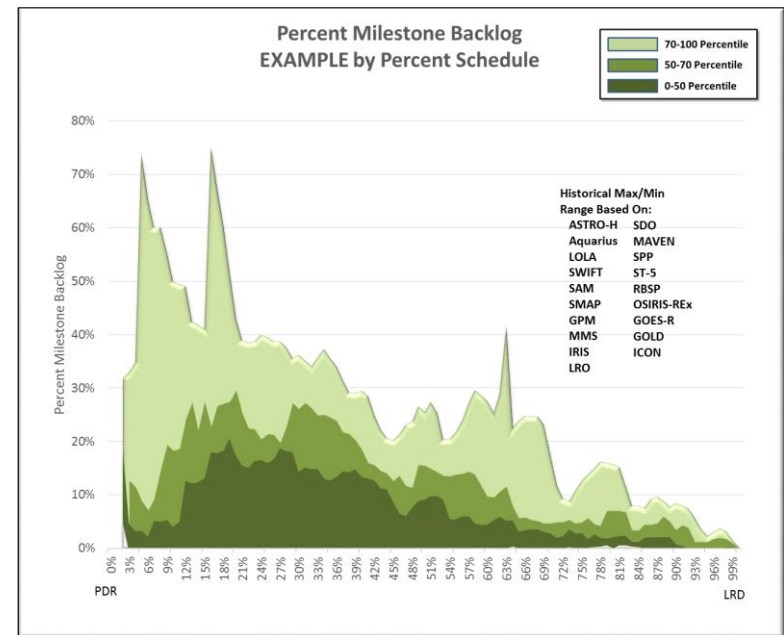schedule axis, the minimum, maximum, 50th percentile and 70th percentile percent backlog was computed in order to develop "shades of normality"

Region of Normality

Percent Milestone Backlog
EXAMPLE by Percent Schedule

Historical Max/Min
Range Based On:
ASTRO-H   SDO
Aquarius   MAVEN
LOLA   SPP
SWIFT   ST-5
SAM   RBSP
SMAP   OSIRIS-REx
GPM   GOES-R
MMS   GOLD
IRIS   ICON
LRO

Region of Normality divided into percentiles

Percent Milestone Backlog
EXAMPLE by Percent Schedule

70-100 Percentile
50-70 Percentile
0-50 Percentile

Historical Max/Min
Range Based On:
ASTRO-H   SDO
Aquarius   MAVEN
LOLA   SPP
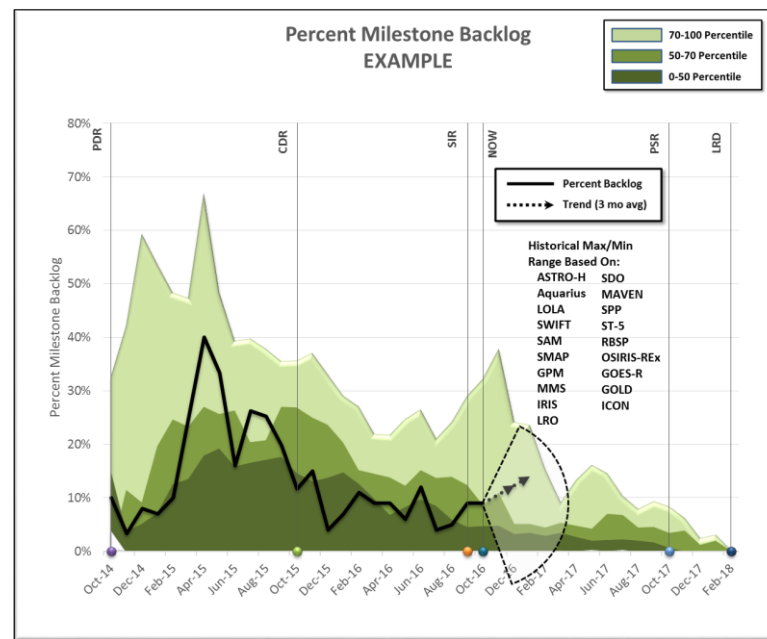SWIFT   ST-5
SAM   RBSP
SMAP   OSIRIS-REx
GPM   GOES-R
MMS   GOLD
IRIS   ICON
LRO

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Development Methodology (6)

- The last step was to map the project being monitored against the region of normality
  - This enables one to gauge the percent milestone backlog performance of the project relative to the collection of projects making up the region of normality
  - This requires re-normalizing the region of normality to the schedule of the project being monitored as described previously (also done using an interpolation scheme)
  - Notice that the normalization back to the project's schedule has resulted in some loss of granularity in the region of normality
  - In this example, the percent milestone backlog for "this month" is about 10% and is projected to increase further
  - However, the backlog is well within the region of normality, indicating that there is no real cause for alarm at this point

Percent Milestone Backlog EXAMPLE

Legend:
- 70-100 Percentile
- 50-70 Percentile
- 0-50 Percentile

Percent Backlog
Trend (3 mo avg)

Historical Max/Min Range Based On:
ASTRO-H, Aquarius, LOLA, SWIFT, SAM, SMAP, GPM, MMS, IRIS, LRO, SDO, MAVEN, SPP, ST-5, RBSP, OSIRIS-REx, GOES-R, GOLD, ICON

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Interpretation

- So, what is this chart telling us?

  - The project being monitored has always had a positive backlog from PDR to the present

  - Looking at time = "now," the backlog is at about 10% and projected to increase

  - But, this is well within the norm for a project at this stage in its lifecycle, and there is currently little cause for alarm

  - The projection arrow exiting the current percent backlog is based on the 3-month average of percent backlog and indicates where we predict the backlog to go if the project continues at its current pace

  - The "cone of uncertainty" provides an indication of milestone backlog behavior over the past six months

  - Bottom line: Yes, there is a backlog, but we're not too concerned about it at this point because many others have been there and recovered

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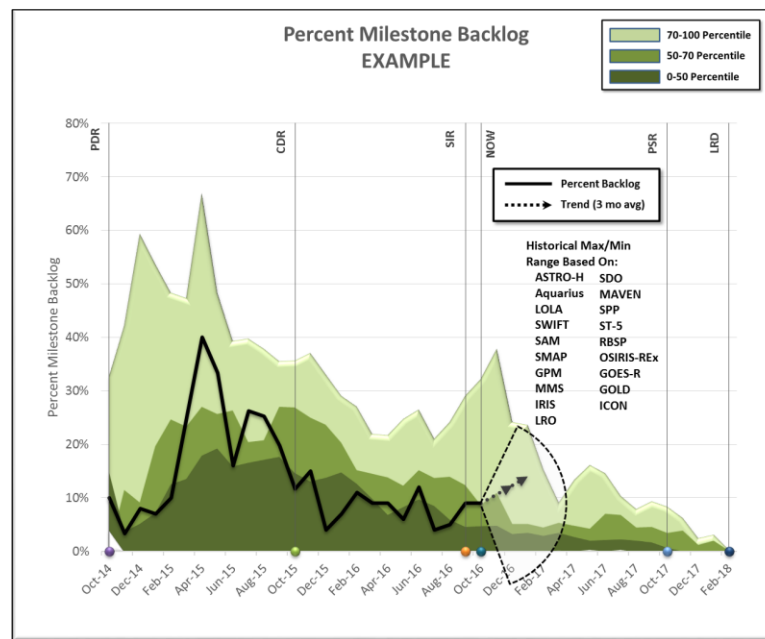
Utility

- The Utility of the Percent Milestone Backlog metric:
  - Gives ability to compare a project of interest to a collection of similar projects
  - Provides an "At-a-Glance" view of the project's milestone completion performance
    - Past
    - Present
    - Future
  - Complements EVM as an indicator of project performance
  - Provides valuable historical context
  - Delivers independent indicator of programmatic health of a development effort
  - Could be applied to other commodities where performance is measured in discrete milestones
    - Industry
    - Other NASA Centers
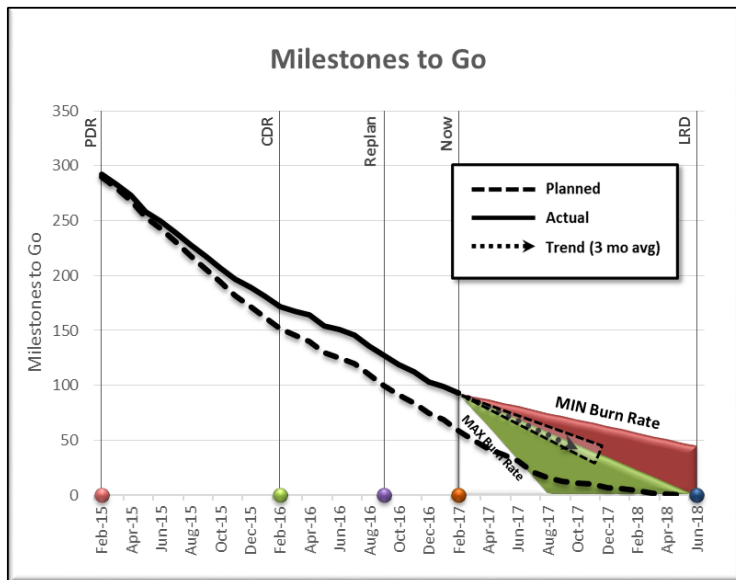   - Other government programs

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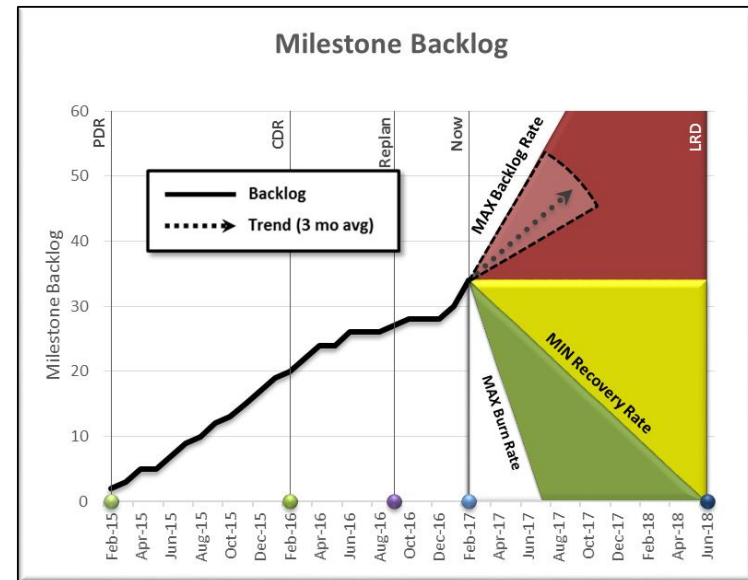- The Percent Milestone Backlog Metric
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Example

- Project XYZ has consistently been lagging in its milestone completion and has been building a backlog

Milestones to Go Lagging the Plan
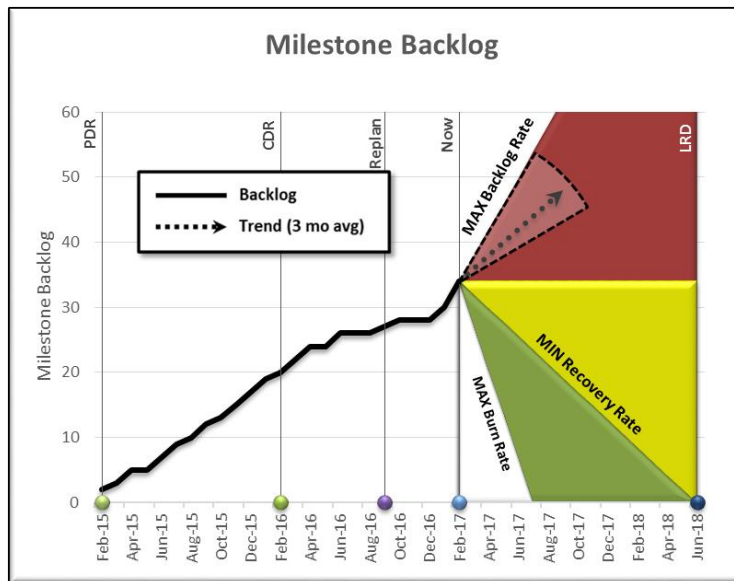
Milestone Backlog has grown continuously

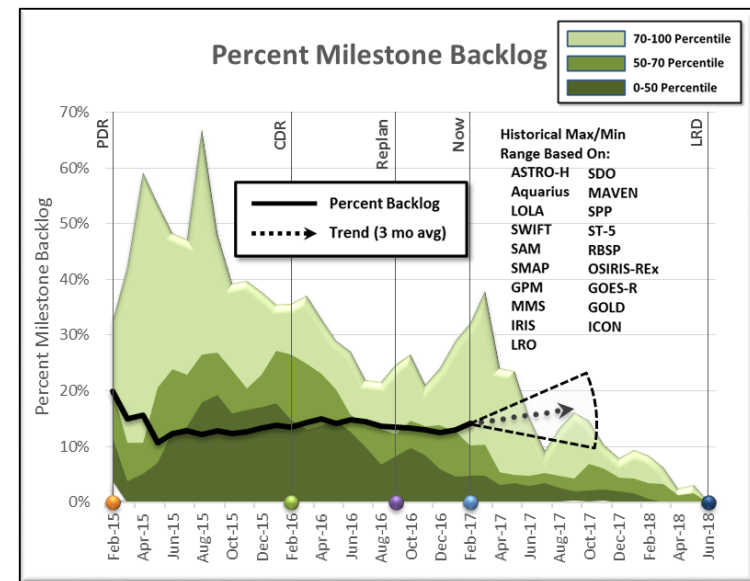- It looks bad, but is Project XYZ really in trouble?

Example

- Despite seemingly bad news, Project XYZ is actually in a better position than many past projects have been at this point in time

Milestone Backlog has grown continuously

Percent Milestone Backlog has remained steady

- The Percent Milestone Backlog metric indicates no cause for alarm…yet. Things are okay for now, but the projection indicates there may be trouble ahead if milestone completion performance doesn't change

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Conclusions and Recommendations

- The Percent Milestone Backlog metric was developed for use by GSFC Flight Projects Directorate as one of several metrics to evaluate programmatic performance of its flight projects

- The Percent Milestone Backlog metric provides actionable insight to management

- The metric could be adapted to a broader range of projects but substantial historical data collection is necessary in order to be useful

- Future work is needed to find more efficient methods for building up the databases and graphs needed to support the Percent Milestone Backlog metric

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